Journal of Agriculture, Food Systems, and Community Development
ISSN: 2152-0801 online
https://foodsystemsjournal.org

# Establishing a community garden in Miawpukek First Nation, Newfoundland, Canada: Research brief on soil contamination challenges and solutions

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Submitted September 11, 2024 / Revised November 19, 2024, and January 13 and 22, 2025 / Accepted January 28, 2025 / Published online May 18, 2025

Citation: Moriarity, R., Wilton, M. J., Liberda, E. N., Drew, T., John, A., Jeddore, H., Sarkar, A., Karagatzides, J. D., & Tsuji, L. J. S. (2025). Establishing a community garden in Miawpukek First Nation, Newfoundland, Canada: Research brief on soil contamination challenges and solutions. *Journal of Agriculture, Food Systems, and Community Development*, *14*(3), 323–337. https://doi.org/10.5304/jafscd.2025.143.004



## Abstract

Indigenous peoples are disproportionately affected by declining food security, particularly in isolated communities like Miawpukek First Nation (MFN), Newfoundland, where geographic isolation limits food access. MFN is only one example of many rural Indigenous communities attempting to establish sustainable local food systems to improve food security. This study aimed to develop safe community garden sites at MFN while addressing potential soil contamination. Soil testing at proposed garden sites revealed inorganic arsenic (As) as the only contaminant of concern, with levels exceeding Canadian agricultural guidelines. To address this, Hügelkultur-style raised beds with imported soil were used. Potatoes grown in these beds had undetectable As levels, making them safe per Health Canada (HC) standards, whereas potatoes grown in the contaminated soil exceeded HC's lower As guideline limit. Peeling these potatoes removed detectable As, leaving the flesh safe to consume,

**Disclosure**
The authors have no conflicts of interest to declare.

**Funding Disclosure**
Funding was received from the Canadian Institutes of Health Research (FRN 166186 and FRN 181128) and the Indigenous Services Canada, Climate Change and Health Adaptation (CCHAP) program.

**Acknowledgments**
We thank the community of Miawpukek First Nation, and the Chief and council for their support.

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while the skins contained levels above HC recommendations. Kale grown in both raised beds and native soil remained within safety limits, suggesting certain crops may be less prone to contamination. These findings stress the importance of soil testing prior to establishing community gardens, especially in rural and remote areas. Food security ensures safe food access for all, but for Indigenous communities, it also fosters food sovereignty and resilience.

**Keywords**
community gardens, arsenic soil contamination, Hügelkultur-style raised-garden boxes, food security, Indigenous communities, Canada

## Introduction and Literature Review

The issue of decreased food security disproportionately impacts Indigenous peoples worldwide due in part to colonialism (Coté, 2016; Council of Australian Governments, 2009; Isaac et al., 2018; Keske, 2021), and other factors, such as geographic isolation (Chen & Natcher, 2019; Council of Canadian Academies 2014; Indigenous Services Canada, 2020), environmental degradation (Moriarity et al., 2024), socio-economic marginalization (Shafiee et al., 2022), and lack of political representation in food governance (Food and Agriculture Organization of the United Nations [FAO], 2021; Whyte, 2017). In Canada (CA), rural and remote Indigenous communities depend on expensive, highly processed imported goods that are of low quality (Friedrich, 2021; Gates et al., 2012, 2016; Spiegelaar & Tsuji, 2013; Spiegelaar et al., 2019) in relation to a subsistence diet (Spiegelaar et al., 2019).

Climate change also presents challenges to food security for rural and remote communities, with unpredictable weather, such as forest fires and floods, disrupting land and air transportation into the communities (Hori et al., 2017a, 2017b, 2018), as well as shifting migratory routes of game birds and the distribution of fish species (Friedrich, 2021; Hori et al., 2012; Spring et al., 2018; Tsuji et al., 2020). Thus, the reliance on agri-food initiatives in these food insecure Indigenous communities is expected. This is especially true when taking into account climate change opportunities in regions once limited by climatic factors. For example, the boreal ecozone of Canada is experiencing new agri-food possibilities due to warming temperatures (Karagatzides et al., 2021; King et al., 2018; Price et al., 2022; Tsuji et al., 2019). As noted in the Ramirez Prieto et al. (2024) review study, community gardens were a popular intervention with respect to the end goal of increasing food security

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in rural and remote communities.

The focus of this research brief is Miawpukek First Nation (MFN), which is located on the island of Newfoundland (Nfld), CA. Households in MFN face ongoing food security challenges due to its remote location, high food costs, and limited access to fresh produce (Food First NL, 2024). Despite the benefits of community gardens for food security, rural Indigenous communities, such as MFN, face unique challenges. These challenges include potential soil contamination risks from past land use or naturally occurring heavy metals in the soil. Existing studies, such as those by Moriarity et al. (2024, 2025) and Wilton et al. (2023), have primarily focused on contamination risks, associated health impacts, and gardening methods, but few have explored practical strategies for implementing safe and sustainable agri-food initiatives in this context. Therefore, this study's objective fills the knowledge gap by testing Hügelkultur-style raised beds with imported soil to mitigate exposure to contaminants, providing a sustainable approach to enhance food security in MFN and similar communities.

## Applied Research Methods

### *Site Assessments: Soil Agricultural Characterization and Contaminant Testing*

The study followed five phases: (1) invitation and ethics approval via telecommunications; (2) chief and council meeting and local assessment (August 2017-October 2019); (3) pilot raised garden beds (August 2019) to estimate soil needs and plan further steps; (4) community-managed phase during the SARS-CoV-2 (COVID-19) pandemic, with researcher involvement via telecommunications; and (5) resumed visits (May–July and September–October 2022) for planting, harvesting, and garden expansion. Specifically, the project's assessment phase involved assessing seven potential sites for the agri-food initiative, including one soil mound (site eight, a raised area of soil with potentially distinct drainage and fertility characteristics) and one peat area (site nine, a region with high organic matter accumulation and water retention properties) identified by MFN land managers and approved by the chief and council (i.e., locally elected government). In August 2017, researchers from the University of Toronto (Toronto, Ontario [ON]), CA), Memorial University (St. John's, Nfld, CA), and local land managers assessed the suitability of these sites for community gardening activities. For sites one to seven, three bulk density soil samples were taken from each site. Further, soil composite samples of approximately 1.1 pound (0.50 kg) were collected using a soil corer. Each site location varied in size and differed by depth to bedrock, impacting the volume per subsample that made up the composite samples. Subsamples were collected using a zig-zag pattern of the whole area, ranging from 3.3 to 4.9 yard (3.0 to 4.5 m) apart, and site samples consisted of 10 to 25 subsamples. Ideally, the subsample collection depth was 0-7.9 inch (0-20 cm) as this is the rooting zone; however, some sites had limited topsoil before reaching bedrock, limiting depth and soil volume per subsample. Sites two and three were the most challenging for collecting soil, with shallow and varied soil depth. Sites one, four, five, and seven had previous agricultural activity (e.g., Christmas tree farm, strawberry field). Soil samples were sent to Laboratory Services, Agriculture and Food Laboratory, University of Guelph (Guelph, ON, CA) for analyses using standard protocols. Soil agricultural analyses included the following: bulk density; soil porosity; pH; conductivity; organic C; total N, P, K, Ca, Mg, S, Mn, Fe, Cu, B, Co, Mi, Zn, and Na; and extractable P, K, Mg, $SO_4$, Mn, and Zn.

Importantly, the soil and peat samples were also analyzed for contaminants and suitability for agricultural use. Portions of the previously described soil and peat samples were tested at the Analytical Services Unit, Queen's University (Kingston, ON, CA), for metals, metalloids, and organochlorines. Soil sampling for these contaminants was conducted as an exploratory measure, as these contaminants are often found in soils. Additionally, the local geology is known to contain naturally occurring As, which raised concerns about potential soil contamination (Moriarity et al., 2024). The soil and peat samples were prepared for analysis using U.S. Environment Protection Agency protocol Method 200.7 (U.S. Environmental Protection Agency, 1994). In brief, samples were acid digested and diluted for metal and metalloid analyses (Ag, Al, total As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Sn, Sr, Ti, Tl, U, V, Zn) by inductively coupled optical emission spectroscopy (ICP-OES). Samples were also analyzed for organochlorines (alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, heptachlor, aldrin, heptachlor epox isomer B, endosulfan I, dieldrin, 4,4-DDE, endrin, endosulfan II, endrin aldehyde, 4,4-DDD, endosulfan sulfate, 4,4-DDT, endrin ketone, methoxychlor, 2,4-DDE, 2,4-DDD, 2,4-DDT, Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260) by gas chromatography with a mass spectrometer. Samples were prepared for gas chromatography by Soxhlet extraction, solid phase extraction, then gel permeation chromatography.

In soil samples from MFN, inorganic As was the only contaminant exceeding the Canadian Council of Ministers of the Environment (CCME) agricultural use guidelines (2007) (see Table 2). All soil sites had total As levels (measured by ICP-OES) above the guidelines, though the guidelines apply specifically to inorganic As, not total As. However, As in soil is typically assumed to exist mainly in inorganic forms, As(III) and As(V). Therefore, to verify and better characterize As inputs to the soils, the soil samples from the three highest total As sites were speciated. Soil sample extraction was through a methanol-enzymatic-heat procedure. High-performance liquid chromatography coupled with inductively coupled plasma mass spectrometry (HPLC-ICPMS) speciated the resultant mixtures. In response to these As findings, the project's steering committee (see Appendix) decided that the community garden would utilize externally sourced soils, which were also tested. These samples did not exceed Canada's agricultural use guidelines for inorganic As (see Figure 3).

### *Community Garden Area and Hügelkultur-Style Garden Beds*

The MFN community garden area was surrounded by trees that provided a natural windbreak, offering protection from strong winds creating a more hospitable microclimate (Karagatzides et al., 2021). Water was available from a creek situated approximately 77 yards (70 meters) away that was gravity fed to the site and stored in food grade intermediate bulk containers. Lab testing at Bureau Veritas (Montreal, Quebec, Canada) confirmed the water source was suitable for agricultural use (n = 2, total As <DL of 0.0010 mg/L, total As matrix spike recovery 94%, total As spiked blank recovery 93%, total As method blank <DL). In 2019, the selected area was cleared of undergrowth and in 2020 the site was divided into quadrants (e.g., school, community, Elders, and fruits and traditional medicinal plants). Hügelkultur-style raised beds were con-

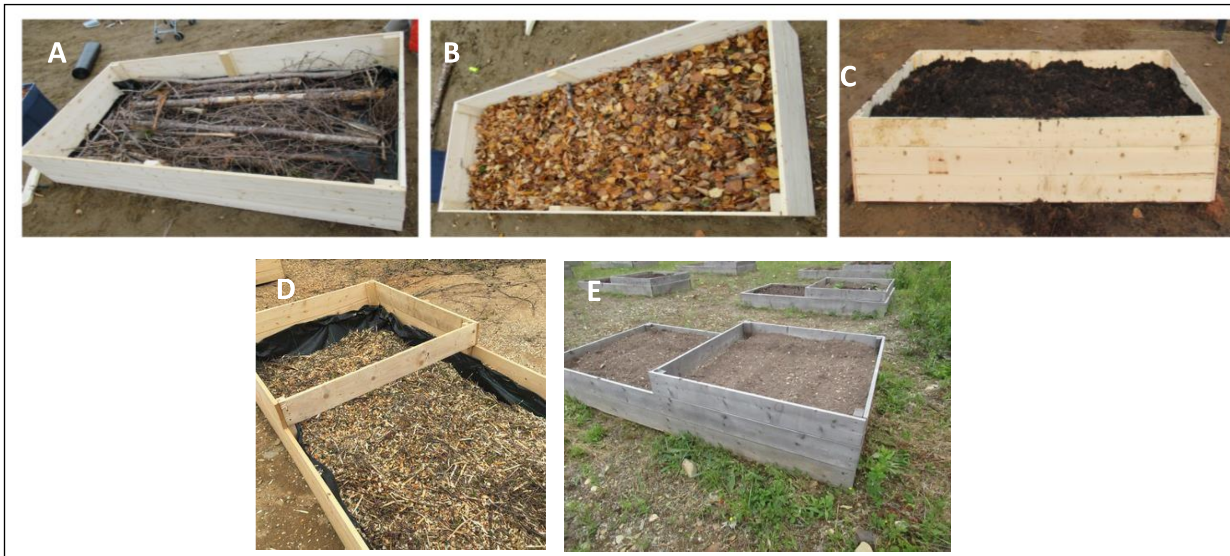
**Figure 1. The Miawpukek First Nation community garden site in 2019 (at left) after being "grubbed," and in 2020 (at right) after Hügelkultur-style garden raised bed construction, prior to the growing season**

structed in each quadrant (Figure 1). Hügelkultur-style raised beds are garden beds built by layering organic materials (e.g., branches, compost) in a mound-like shape structure, then covering them with soil (Chalker-Scott, 2017). This design enriches the soil as the organic matter decomposes and improves water retention, creating ideal conditions for plant growth.

Furthermore, Hügelkultur-style garden beds (Figure 2) were utilized because they were found to be effective in another First Nations community in the boreal region of subarctic Canada (Wilton et al., 2023). The Hügelkultur-style was modified to include a box structure (Wilton et al., 2023)—either one or two-tiered—containing organic and soil layers, permitting a flat surface for cultivation. Alder trees were plentiful at the site and abundant in the region; thus, alders were shredded using a standard yard-waste chipper-shredder creating mulch (Figure 2).

In addition to the May 2020 construction of raised Hügelkultur-style beds with imported soil, a temporary bed using the "lazy bed" cultivation approach was developed in the community garden to determine As concentrations in the edible portions of crops grown in local soil. Lazy bed cultivation is a traditional planting method that involves creating raised rows, or ridges, separated for drainage. This method improves soil warmth, drainage, and aeration to support crop growth in challenging conditions (Omohundro, 1985). Community members had expressed some concern with respect to As contamination in crops grown inground. Lazy beds, also known as ridge and furrow, consist of long rows of raised soil known as ridges, separated by lower troughs called furrows. This land cultivation method has been used for centuries in various parts of the world to optimize crop growth conditions, especially in areas with specific climate and soil challenges (Erickson, 2021; Langewitz et al., 2022). For over 250 years, the lazy bed technique has been utilized along the coastal communities of Nfld, including by people (Indigenous and settlers) living along the Conne River estuary (Mackey & Bernard, 1988; Omohundro, 1985; Prins, 1997). Located at the edge of the Elders' section of the community garden, two mounded 16.4 yard (15 m) long rows were constructed with the assistance of a small excavator to reduce manual labor. The mounds were approximately one meter in width with a trench approximately 3.9 inch (10 cm) deep and 23.6 inch (60 cm) wide, making the total bed depth near 9.8 inches (25 cm). The MFN community garden coordinator constructed and designed

**Figure 2. Examples of Hügelkultur-style garden beds with branches (A), other organic material (B), and the top layer of imported soil (C). Examples of two-tiered Hügelkultur-style garden beds with shredded alder (D) and topsoil (E).**



the lazy beds. No soil amendments were added to the mounds. Historically, potato lazy beds in Newfoundland were replenished with stable manure and seaweed (Omohundro, 1985).

### *Food Safety: Potato and Kale (2020)*

Potatoes, carrots, cabbage, and kale were planted in Hügelkultur-style beds and lazy bed rows (June 24–July 9, 2020) due to their adaptability to local growing conditions and alignment with local dietary preferences and taste. At the time of harvest (October 8, 2020), potato and kale were the only two crops that grew relatively well in the lazy bed. Thus, As analyses were limited to potato and kale to allow for As comparisons between crops grown in Hügelkultur-style beds and in the lazy bed rows.

In the school, community, and Elders' sections of the community garden, two Hügelkultur-style beds were selected per section. From these two Hügelkultur-style beds per section ($n$ = 6), one potato plant per bed was selected, and from each plant three potatoes were harvested for As analyses. For the two lazy bed rows, three potato plants per row were selected ($n$ = 6), and three potatoes per plant were harvested. All potatoes were rinsed with distilled water, left to air dry, and then weighed before packing. Potatoes from one plant were put into their respective labelled paper bags. The samples were then put in a cardboard package and couriered to Queen's University for As analysis. At the laboratory, technicians prepared whole potatoes (skin + flesh) from Hügelkultur raised beds (R) for As analysis. However, for potatoes grown in lazy beds, the technicians cut each potato in half; one of the halves had the skin removed by peeling. Thus, the potatoes grown inground (I) in the lazy beds were divided into three categories prior to As analyses: whole (skin + flesh); skin only; and flesh only. All samples were characterized for total As by inductively coupled plasma mass spectrometry.

From the same Hügelkultur beds as the potato samples, three kale plants were selected per bed ($n$ = 6), and from each kale plant, three leaves were collected for analyses. For the lazy beds, three kale plants per row were randomly selected ($n$ = 6), and three leaves were collected from each plant. Kale plants were not rinsed and were dried overnight using a food dehydrator with parchment paper overlaying the racks. Each kale plant had a separate rack for drying, and the drying sessions did not combine kale samples sourced from different soil conditions. Kale leaves from one plant were put into its own labelled paper bag and sent to Queen's University for analyses.

## Results

### *Site Assessments for Soil Agricultural Characterization and Soil Contaminant Testing*

The soil in each site was classified as acidic (pH range 4.6–5.9). Results of the other soil parameters are presented in Table 1.

For all soil and peat sites, 1016, 1221, 1232, 1242, 1248, 1254, 1260 concentrations were less than the detection limit (DL) of 0.10 ug/g for the instrument. Quality assurance and control (QA/QC) measures were within acceptable parameters: blank <DL, duplicate <DL, and control 94% of control target. Similarly, all other organochlorines were found to be less than the DL (< 1.0 ng/g for DDT and metabolites, < 5.0 ng/g for Endrin Aldehyde, and < 2.0 ng/g for all other organochlorines). QA/QC measures were all within acceptable parameters: blank <DL for all respective organochlorines, duplicate <DL for all respective organochlorines, and control 83%–112% of control target. For all metals, metalloids, and organochlorines tested, the only contaminant of concern with respect to the CCME (2007) agricultural use guidelines was inorganic As (Table 2). Speciation of soil samples from the three most contaminated sites revealed that the majority of the As was inorganic, mainly as As(V), with smaller amounts as As(III) (Table 2).

Soil samples from external distributors met the CCME (2007) guideline of < 12 μg/g inorganic As for agricultural use (Figure 3). Note that values reported for external soil distributors (i.e., external site one and two) were an overestimation of As concentration when compared to the CCME guideline because the concentrations reported are for total As μg/g and not inorganic As.

### *Food Safety: Potato and Kale (2020)*

Almost all samples from potatoes grown in the raised boxes and imported soil had total As concentrations <DL (0.05 μg/g), with one sample at the limit of detection (0.052 μg/g). Thus, all potatoes grown in the raised boxes and imported soil were safe to eat when compared to Health Canada's (Health Canada [HC], 2022) consumption guidelines for inorganic As in rice (Figure 4). For potatoes grown in the native soil, the whole potato had elevated total As concentrations that ranged between 0.07–0.21 total As μg/g as a group. Potatoes grown inground exceeded the lower limit of the HC's guideline of 0.10 inorganic As μg/g for rice-based foods for consumption by infants and young children (Figure 4); inorganic As for the guidelines was estimated as the sum of As(III) and As(V). For white rice, the limit is 0.20 inorganic As μg/g, while for brown rice the limit is 0.35 inorganic As μg/g according to HC guidelines (Figure 4).

For potatoes grown in the native soil, when the skin was removed from the potato flesh and skin and flesh were analyzed separately, total As was undetectable for all flesh samples (i.e., <DL total As of 0.05 μg/g; Figure 4). By contrast, total

**Table 1. Soil agricultural characteristics for Sites 1-8, and peat characteristics for Site 9**

| Parameter | Site 1 (soil) | Site 2 (soil) | Site 3 (soil) | Site 4 (soil) | Site 5 (soil) | Site 6 (soil) | Site 7 (soil) | Site 8 (soil) | Site 9 (peat) |
|---|---|---|---|---|---|---|---|---|---|
| Bulk density (g $cm^{-3}$) | 1.30 | 1.26 | 1.20 | 1.25 | 1.25 | 1.00 | 1.20 | 1.22 | 37.3 |
| Soil porosity (%) | 51.0 | 52.5 | 54.8 | 52.8 | 52.8 | 62.3 | 54.7 | 54.7 | |
| pH | 5.9 | 5.1 | 4.6 | 5.3 | 5.2 | 4.8 | 5.6 | 5.3 | |
| $pH_{buffer}$ | 6.3 | 5.8 | 5.4 | 6.2 | 6.2 | 5.8 | 6.0 | 6.4 | |
| CEC (cmol*$kg^{-1}$) | 1.41 | 4.92 | 7.09 | 1.41 | 1.95 | 5.81 | 3.63 | 1.25 | |
| Organic C % | 1.49 | 2.86 | 4.99 | 2.01 | 1.85 | 2.32 | 2.80 | 1.22 | 37.3 |
| Total N % | 0.12 | 0.19 | 0.31 | 0.15 | 0.14 | 0.18 | 0.19 | 0.10 | 0.75 |
| C:N | 12.42 | 15.05 | 16.10 | 13.40 | 13.21 | 12.89 | 14.74 | 12.20 | |
| Total P (mg $kg^{-1}$) | 280 | 390 | 360 | 380 | 270 | 220 | 470 | 320 | 120 |
| $P_{extractable}$ (mg $L^{-1}$) | 3.1 | 3.2 | 16.0 | 2.5 | 1.4 | 9.9 | 15.0 | 4.4 | |
| Total K (mg $kg^{-1}$) | 530 | 370 | 720 | 800 | 780 | 920 | 570 | 870 | 350 |
| $K_{extractable}$ (mg $L^{-1}$) | 28 | 38 | 54 | 16 | 19 | 23 | 91 | 22 | |
| Total Ca (mg $kg^{-1}$) | 520 | 300 | 270 | 290 | 180 | 180 | 280 | 460 | 310 |
| Total Mg (mg $kg^{-1}$) | 4600 | 3000 | 2500 | 5700 | 4800 | 8500 | 3700 | 6500 | 1700 |
| $Mg_{extractable}$ (mg $L^{-1}$) | 16 | 34 | 77 | 14 | 15 | 40 | 54 | 23 | |
| Total S (mg $kg^{-1}$) | 120 | 190 | 180 | 220 | 190 | 110 | 210 | 110 | 200 |
| $SO4_{extractable}$ (mg $L^{-1}$) | <2.5 | <2.5 | 14.6 | <2.5 | 2.81 | 16.1 | <2.5 | 6.23 | |
| Total Mn (mg $kg^{-1}$) | 530 | 1000 | 750 | 930 | 750 | 310 | 500 | 580 | 96 |
| $Mn_{extractable}$ (mg $L^{-1}$) | 3 | 24 | 29 | 13 | 9.3 | 17 | 12 | 23 | |
| Total Fe (g $kg^{-1}$) | 29 | 33 | 33 | 39 | 33 | 32 | 28 | 30 | 7.7 |
| Total Cu (mg $kg^{-1}$) | 14 | 13 | 23 | 27 | 23 | 8.6 | 12 | 19 | 7.1 |
| Total B (mg $kg^{-1}$) | 2.3 | 2.0 | 2.5 | 2.3 | 2.1 | <2 | 2.0 | <2 | <2 |
| Total Co (mg $kg^{-1}$) | 10 | 9.5 | 15 | 9.5 | 9.9 | 9.4 | 12 | 32 | |
| Total Ni (mg $kg^{-1}$) | 41 | 32 | 28 | 34 | 28 | 34 | 20 | 29 | 16 |
| Total Zn (mg $kg^{-1}$) | 42 | 45 | 36 | 66 | 52 | 52 | 38 | 49 | 16 |
| $Zn_{extractable}$ (mg $L^{-1}$) | 0.15 | 0.71 | 2.9 | 0.22 | 0.22 | 1.50 | 0.37 | 0.19 | |
| Total Na (mg $kg^{-1}$) | <75 | <75 | <75 | <75 | <75 | <75 | <75 | <75 | <75 |

As levels in the skin samples ranged from 0.99–2.0 total As µg/g, with all potato skin samples exceeding the HC guideline (Figure 4).

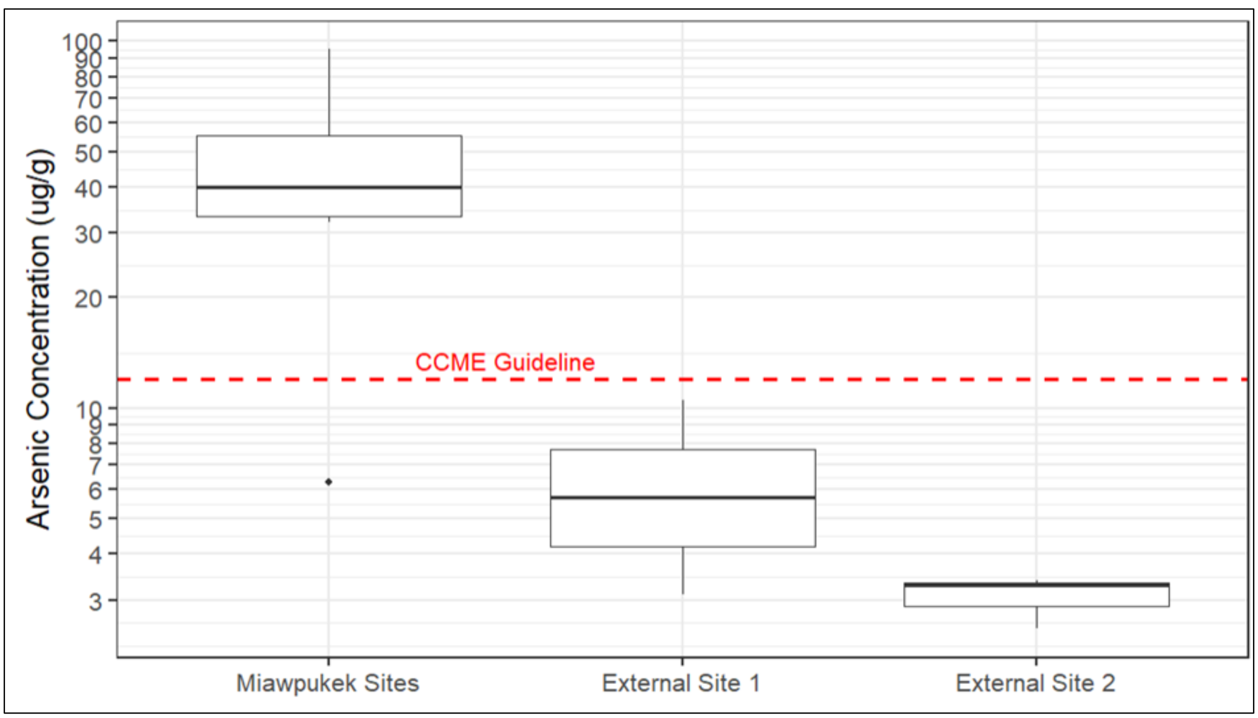
Samples for kale grown in raised beds (range: < 0.05–0.10 total As concentrations µg/g) and inground (range: < 0.05–0.096 total As concentrations µg/g) did not exceed HC guideline's lower limit of 0.10 inorganic As µg/g for rice-based foods for consumption by infants and young children. Lastly, QA/QC measures for As determination for potatoes and kale were acceptable. For potatoes and kale respectively, $n$ = 5, duplicates within 92-114% of original values; $n$ = 4, blanks <DL 0.05 µg/g; $n$ = 4, controls within 96–108% of control target; and $n$ = 4, results within 85–110% of certified reference materials.

**Table 2. Total As in soils and peat, with speciation of soil samples from the three most highly contaminated sites**

| Parameter | Site 1 (soil) | Site 2 (soil) | Site 3 (soil) | Site 4 (soil) | Site 5 (soil) | Site 6 (soil) | Site 7 (soil) | Site 8 (soil) | Site 9 (peat) |
|---|---|---|---|---|---|---|---|---|---|
| Total As (µg/g) | 34 | 43 | 59 | 57 | 50 | 95 | 32 | 37 | 6.3 |
| Arsenite (As(III)) (µg/g) | — | — | 0.189 | 0.286 | — | 0.270 | — | — | — |
| Arsenate (As(V)) (µg/g) | — | — | 48.2 | 36.3 | — | 74.1 | — | — | — |
| Inorganic As (µg/g) | — | — | 48.4 | 36.6 | — | 74.4 | — | — | — |
| Inorganic As (% total) | — | — | 82.0 | 64.0 | — | 78.0 | — | — | — |

*Note*: the CCME (2007) guidelines for agricultural use is 12 µg/g of inorganic As.

**Figure 3. A comparison of total As in soils sampled from potential community garden sites to the CCME (2007) guideline of 12 µg/g of inorganic As for agricultural use**



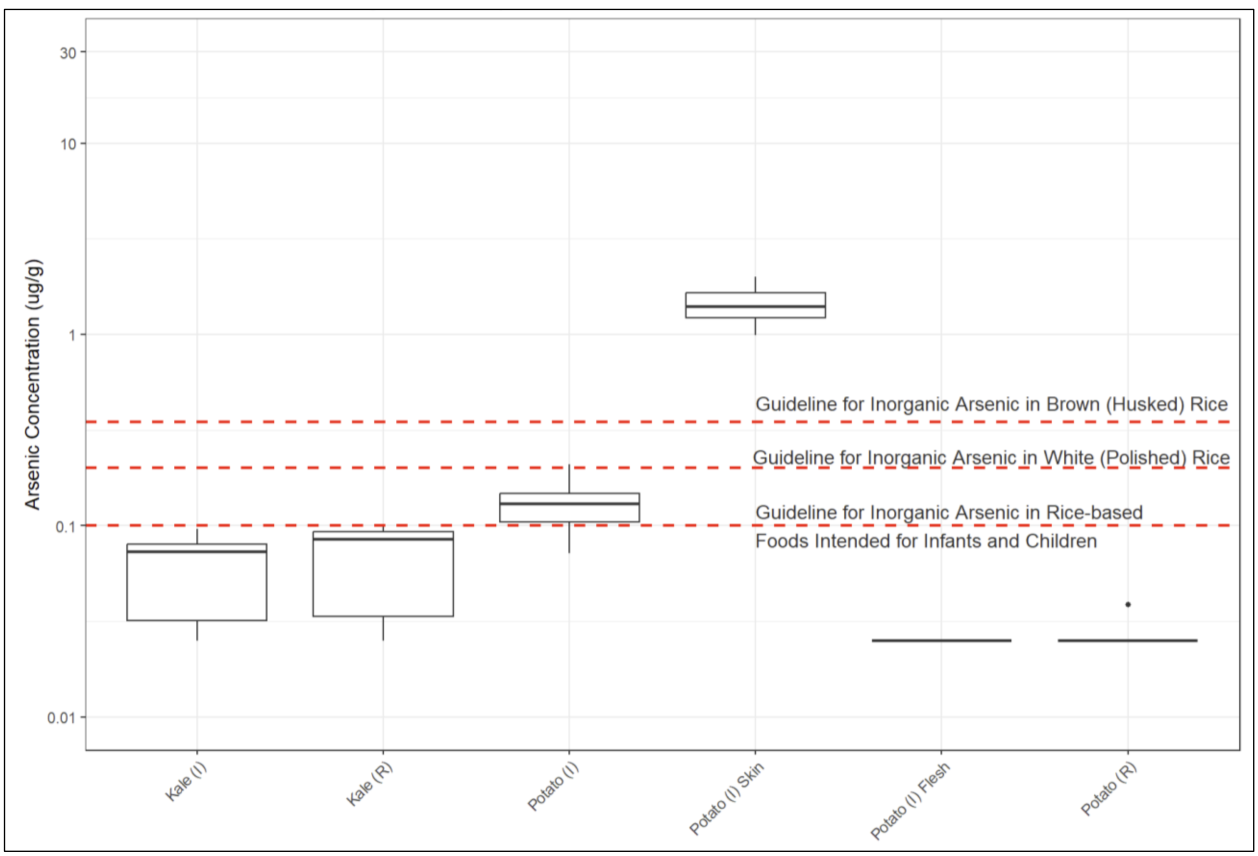
## Discussion

We limit our discussion to the agricultural characteristics of soil from potential community garden sites, as considerations about crop suitability and soil fortification became irrelevant once the decision was made to use imported soil from a distributor. However, we do present the results of the soil agricultural characterization for completeness. The tested soils were acidic, so the community treated them with lime to raise the pH. Increasing soil pH (range: 6.5 to 7.5) can reduce As bioavailability by promoting the less mobile As(V) form over the more soluble As(III), which predominates in acidic conditions (Fitz & Wenzel, 2002).

### *Site Assessments: Soil Agricultural Characterization and Soil Contaminant Testing*

High total As levels in soil were unsurprising, as rural Nfld communities often report elevated As concentrations in well water from volcaniclastic bedrock (Chafe et al., 2018). In response to the soil findings, the steering committee decided that the community garden would utilize imported soil, but only from soil distributor two, as the soil was found to be the least contaminated with As of the two possible choices. Purchasing soil for establishing community gardens is occasionally used in various settings, from urban to rural, as it ensures soil quality (e.g., free of contaminants) and simplifies setup. However, it can be costly, less sustainable, and may not match local conditions (e.g., drainage properties, nutrients) (Karanja et al., 2012; Thompson et al., 2018). Only the peat site was relatively uncontaminated, which we suspect is due to its high organic matter content and minimal prior disturbance. It may be used in the future for soil

**Figure 4. A comparison of total As concentrations in kale grown inground (I) in native soil, kale grown in raised beds with imported soil (R), whole potatoes grown inground (I) in native soil (the skin of potatoes grown inground (I) in native soil, and the flesh of potatoes grown inground (I) in native soil), and whole potatoes grown in raised beds with imported soil (R)—to the HC guidelines for inorganic As µg/g in rice (and rice-based products)**



augmentation. The soil imported to MFN for this study was sourced from a Nfld landscape supplier that asked not to be identified, and was a blend composed of 50% screened topsoil, 30% peat, and 20% compost. The topsoil component was classified as loam, specifically an orthic humo-ferric podzol (Sanborn et al., 2011).

***Food Safety: Potato and Kale (2020)***

Worldwide, no guidelines exist for the consumption of potatoes or kale with respect to total As. Thus, caution is advised when interpreting the results of the present study because the HC guidelines are for inorganic As in rice and our results are for total As (HC, 2022). Importantly, rice is a super accumulator of As, so conclusions must be tempered. Nonetheless, all whole potatoes (i.e., flesh and skin) sampled from the raised beds with imported soil were found to have As concentrations at or below the DL, indicating that whole potatoes grown in the raised beds were safe to eat. In contrast, whole potatoes grown in local soil had elevated levels of total As above the HC guideline for human consumption. However, when the potatoes grown in local soil had the skin removed, and the potato skin and flesh analyzed separately for total As, the flesh of the local soil-grown potato was similar to the whole potato grown in imported soil. Noteworthy, the skin of the potato grown in local soil had total As levels higher than all potato sample types including the whole potato grown in local soil. In other words, the greatest concentration of total As occurred in the skin of local-soil grown potatoes. Since the whole potatoes were only lightly rinsed with distilled water in the present study, we do not know whether As-contaminated soil particles are associated with the potato skins grown in local soil or whether there was As uptake into the potato skins. Therefore, we recommend peeling all potatoes and other root crops grown in MFN's natural soil before consumption.

Kale grown in raised beds and in lazy beds had similar concentrations of total As, and all samples did not exceed the HC guideline threshold for inorganic As. The comparable results for kale grown in different soils may be due to the fact that kale samples had not been rinsed in distilled water prior to being sent for analysis. Ideally, the kale samples should have been washed with distilled water and spun in a salad spinner, which was our planned method. However, because of the COVID-19 pandemic travel restrictions and community lockdowns, the university coordinator of the project was not in the community to supervise the harvest and preparation of the samples, and did not find out about the missed step of rinsing until after the fact. Even with imported soil, kale should be washed due to potential contamination from airborne soil particles (e.g., from wind erosion). Our recommendation to residents of MFN based on the kale results is that any above-ground crop or medicinal plant should be washed thoroughly to remove any soil particles prior to consumption.

Community garden organizers can manage As and potentially other contaminant bioavailability by raising soil pH with agricultural lime (Fitz & Wenzel, 2002). Iron or phosphate amendments may also reduce bioaccessible As (Cutler et al., 2014). However, soil testing may need to be conducted through external labs at some point. Until laboratory testing becomes available, adding compost to soil can help improve soil stability by enhancing microbial activity and potentially limiting the availability of inorganic As and other soil contaminants (Huang et al., 2016). In high-contamination areas, implementing raised beds filled with off-site, agriculturally suitable soil provides a safe alternative when local soil poses safety concerns. However, raised enclosed beds, such as Hügelkultur beds, can increase construction costs, which depend on factors like location remoteness and availability of materials (Wilton et al., 2023). In this study, the average cost per bed was CA$104, including lumber, screws, landscape fabric, and delivered soil. Lastly, the study's findings on improving food security in MFN are relevant to many other rural and remote communities across Nfld, the rest of CA, and around the world, as shown in Moriarity et al. (2024). It should be stressed that soils from potential community garden areas should always be tested for contaminants, such as organochlorines, metals, and metalloids, because food security is much more than the quantity of food produced, it is also the quality of food. Even if soil appears to be pristine, or even if the soil is imported, the soil may still be found to be contaminated upon analysis (Moller et al., 2018; Moriarty et al., 2024).

## Conclusions

This study emphasizes the importance of assessing soil quality and contamination levels when establishing community gardens. High As concentrations in local soils prompted the use of imported soil to ensure safer agricultural practices and food consumption. The findings indicated that potatoes grown in imported soil were safe, while those grown in local soil needed peeling to avoid increased As exposure. Kale grown in both soil types remained within safe consumption limits, though thorough washing was advised. These results are significant for community partners and researchers, providing practical guidance for managing soil contamination and enhancing food security. Future research should investigate the long-term sustainability of using imported soil, effective soil remediation methods, and develop comprehensive safety guidelines for consuming crops grown in contaminated soils.

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Journal of Agriculture, Food Systems, and Community Development
ISSN: 2152-0801 online
https://foodsystemsjournal.org

## Appendix

### *Steering Committee: Miawpukek First Nation Community Garden Project*

The partnership framework comprises decisionmakers, chosen for their expertise and project interest, and advisors, who are Miawpukek residents and academics. The steering committee (Figure A1), which is responsible for planning and operational management, meets monthly to review outcomes and seek long-term sustainability strategies.

The technical working committee consists of the academic garden coordinator and community-based garden manager. The technical working committee communicates weekly, and they put the actions in place that were directed by the steering committee and are guided by advisory boards and the inputs of residents. The Indigenous advisory committee liaises with the community, preserves Indigenous knowledge, and oversees intellectual property rights. The academic advisory committee, with diverse external experts, offers specific project recommendations as needed. Feedback was welcomed from residents. This feedback, receivable by any partnership member, was reviewed by a designated committee and the steering committee.

**Figure A1. Steering Committee Partnership Structure**